PRE-FILED TESTIMONY
OF LENNART HARDELL, MD, PhD
MPUC Docket No. 2011-00262

Q. Please state your name and address.

A. Lennart Hardell, MD, PhD
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Q. Briefly state your occupation, educational background and current employment.

A. I am a professor of oncology at Orebro University Hospital specializing in the epidemiological research studying cancer risks related to exposure to environmental toxins, including electromagnetic radiation. I have been a specialist in oncology since 1979. My work as an oncologist has included medical treatment of cancer patients and radiotherapy. In parallel with that work I have performed epidemiological research mostly on risk factors for cancer. Attached as Exhibit A is my curriculum vitae (C.V.).

Q. Are you a member of any professional organizations? If so, please list.

A. This is listed in my C.V.

Q. Have you authored any papers or journal articles?

A. I have published more than 300 scientific articles in peer-reviewed scientific journals, chapters in books, and commentaries. In addition I have published 149 abstracts for scientific meetings and shorter communications. A full list is shown on Exhibit A.

Q. Briefly describe your work and experience related to the study of health risks related to electromagnetic fields and radiofrequency electromagnetic fields in the 30 MHz to 300 GHz range (RF-EMF). Identify any studies or published writings on the subject.

A. In 1995 we published our evaluation of cancer risks associated with exposure to extremely low frequency electromagnetic fields (ELF-EMF) in a peer-reviewed scientific journal as supplement (Hardell et al 1995).[1]

After that I have participated in and been the lead investigator and author of a large number of scientific studies on use of mobile phones and cordless phones and the risk for certain malignant diseases (brain tumors, salivary gland tumors, testicular cancer, non-Hodgkin lymphoma, malignant melanoma). This has resulted in more than 80 publications that are listed in Exhibit A. I have also on numerous occasions been invited to participate in scientific meetings to present the results from our studies in this area. I am regularly referee for journals on submitted scientific articles. I was invited to be part of the expert panel at IARC in May 2011 on the evaluation of scientific evidence of the carcinogenic effects of RF-EMF. Recently I was invited to submit an article on this topic to the publication Late Lessons from Early Warnings, volume II; European Environment Agency, Copenhagen, as well as the BioInitiative 2012 Report, and to different journals. I have also supervised several medical dissertations within epidemiology, mostly on risk factors for cancer.

Q. Are you familiar with other peer-reviewed epidemiological studies addressing the risk of cancer, disease, or other adverse health effects resulting from the exposure to RF-EMF, meaning radio frequency radiation at levels below which thermal effects are known to occur?

A. Yes. Since this is one of my specialties I have studied and scrutinized most of the peer-reviewed studies that have been published on the subject since the 1990's. It has also been part of being a scientific expert, etc see above.

[1] Studies and papers cited in this testimony are listed alphabetically on Exhibit B.

Q. Have you performed any meta-analyses of different studies on the subject? Briefly describe the work you have produced conducting meta-analyses and the conclusions.

A. Yes, my co-workers and I have performed three meta-analyses of the risk for brain tumors associated with use of wireless phones.

The first one was published in 2007 in Occupational Environmental Medicine (Hardell et al 2007a). Of the 16 case-control studies that were published on this topic, 11 gave results for 10 years use or more (latency period = time from first use of the mobile phone until the brain tumor was diagnosed). An association with acoustic neuroma was found in four studies in the group with at least 10 years use of a mobile phone. Six studies gave results for malignant brain tumors in that latency group. All gave increased odds ratios (OR), especially for ipsilateral exposure, that is the phone had been used on the same side of the brain as the tumor appeared. In the meta-analysis, ipsilateral cell phone use gave OR = 2.4, 95% confidence interval (CI) = 1.1 - 5.3, for acoustic neuroma and OR = 2.0, 95 % CI = 1.2 - 3.4, for glioma using a tumor latency period of 10 years and more.

The next overview including meta-analysis was published in Pathophysiology in 2009. In summary the review yielded a consistent pattern of an increased risk for glioma and acoustic neuroma after >10 years mobile phone use, but not for meningioma. We concluded that current standards for exposure to microwaves during mobile phone use were not adequate for long-term exposure and needed to be revised (Hardell et al 2009).

Our most recent meta-analysis was published Dec 20, 2012 in Pathophysiology (Hardell et al 2012). We gave an overview of current epidemiological evidence for an

increased risk for brain tumors including a meta-analysis of the Hardell group and Interphone results for mobile phone use. These studies with results for longest duration of use served as important bases for IARC classification of RF-EMF as possible human carcinogen, see discussion below.

In contrast to the Hardell group studies, results for cordless phones are lacking in Interphone and the other studies in this area. Cordless phones emit similar RF-EMF emissions as mobile phones. Thus, including such use in the 'unexposed' group would obscure the possibility to identify an increased risk for cancer associated with use of wireless phones (mobile phones and cordless phones). It is like studying the risk for lung cancer among smokers and disregarding use of one type of cigarettes (e.g. one brand) and to include that group in the non-smoking group. Since also use of cordless phones emit RF-EMF emissions with increased risk for brain tumors in the Hardell group studies, excluding such use from the exposed groups (instead included in the 'unexposed' group) results in lower risk estimates and diminishes the possibility to find an increased risk.

The 2012 meta-analysis gave for glioma in the most exposed part of the brain, the temporal lobe, OR = 1.71, 95 % CI = 1.04-2.81 in the $\geq$ 10 years (>10 years in the Hardell group) latency group. Ipsilateral mobile phone use $\geq$ 1,640 hours in total gave OR = 2.29, 95 % CI = 1.56-3.37. The results for meningioma were OR = 1.25, 95 % CI = 0.31-4.98 and OR = 1.35, 95 % CI = 0.81-2.23, respectively. Regarding acoustic neuroma ipsilateral mobile phone use in the latency group $\geq$ 10 years gave OR = 1.81, 95 % CI = 0.73-4.45. For ipsilateral cumulative use $\geq$ 1,640 hours OR = 2.55, 95 % CI = 1.50-4.40 was obtained. Also, use of cordless phones increased the risk for glioma and acoustic neuroma in the Hardell group studies. This meta-analysis confirmed previous

findings of an increased risk for glioma and acoustic neuroma associated with use of wireless phones (Hardell et al 2012).

In summary, there is sufficient evidence to conclude that RF-EMFs are bioactive and have a potential to cause health impacts. There is a consistent pattern of increased risk for glioma and acoustic neuroma associated with use of wireless phones (mobile phones and cordless phones). The current safety limits and reference levels are not adequate to protect public health. New public health standards and limits are needed.

Q. What information is there about glioma patient survival and is that relevant to the causal association between glioma and cell phone RF-EMF exposure?

A. A carcinogenic effect of RF-EMF emissions would be strengthened if exposure might negatively correlate with survival of glioma patients. The Hardell group analysed survival of glioma patients in the study period 1997-2003. Decreased survival of glioma cases (glioblastoma multiforme) with long-term and high cumulative use of wireless phones was found (Hardell, Carlberg 2012). Thus, this is an additional finding that adds to the biological relevance of a causation of glioma by exposure to RF-EMF. The results show an increased risk for glioma for wireless phone use but also worse outcome of the disease.

It should be added that a poorer survival among children with acute lymphoblastic leukaemia exposed to ELF-EMF has been reported in two studies (Foliart et al 2006, Svendsen et al 2007). These findings certainly strengthen a causal association between exposure to ELF-EMF and childhood leukaemia.

Q. Experts testifying for CMP, Drs. Bailey and Shkolnikov, emphasized the importance of a Danish cohort study on mobile phone users and cancer risks. Are you familiar with that study?

A. Yes.

Q. Are the results in the Danish cohort study reliable and based on sound epidemiological methods?

A. No. This was a record linkage study partly funded by two Danish telecom-operating companies, TeleDenmark Mobil and Sonofon, with no individual exposure data. It has produced four articles that we have made a thorough review of (Söderqvist et al 2012a). We concluded that its many limitations - embedded in the study design from the very beginning and mainly related to poor exposure assessment - cloud the findings of the four reports to such an extent that render them uninformative, at best. At worst, they may be used in a seemingly solid argument against an increased risk– and the reader may not understand that the Danish cohort study is a textbook example of a study design that precludes the possibility to find an increased risk, as we have discussed in our review. The term *business bias* may apply to the Danish cohort study, a terminology recently discussed by Levis et al (2012). There is always a potential of conflicts of interest when a study is sponsored by the industry (Hardell et al 2007b)

The Danish cohort study was included in the IARC evaluation of RF-EMF as human carcinogen, but the conclusion was that "phone provider, as a surrogate for mobile phone use, could have resulted in considerable misclassification in exposure assessment." (Baan et al 2011). Thus, the Danish cohort study was considered to be uninformative as to cancer risks from mobile phone use.

Q. Is there a potential for adverse health effects from RF-EMF radiation from mobile phone base stations?

A. Yes. By searching PubMed, we identified a total of 10 epidemiological studies that assessed for putative health effects of mobile phone base stations. Seven of these studies explored the association between base station proximity and neurobehavioral effects and three investigated cancer. We found that eight of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances < 500 meters from base stations. None of the studies reported exposure above accepted international guidelines, suggesting that current guidelines may be inadequate in protecting the health of human populations (Khurana et al 2010). The results and discussion by the Salford group on non-thermal effects on the blood-brain-barrier and neuronal death in their experimental studies are most relevant in this context (Salford et al 2012), see also discussion below.

Q. Based on all of the epidemiological evidence available, please state your opinion about the extent of the association between exposure to RF-EMF and cancer.

A. There is a consistent pattern of an increased risk of glioma (malignant brain tumor) and acoustic neuroma (benign tumor on the 8th cranial nerve) associated with use of wireless phones (both mobile phones and cordless phones). The increased risk is highest for tumors on the same side of the head (ipsilateral) as the phone has been used during long-term and highest cumulative use in hours over the years. The conclusion is based on all studies, especially those that provide results for at least 10 years latency period (time from first use until tumor diagnosis) for use of wireless phones.

It should be noted that this association was not found for meningioma. Patients with that tumor type were included in the same studies on glioma and acoustic neuroma. A systematic bias in the studies that would explain the results for glioma and acoustic neuroma would also have been the case for meningioma. Thus, different results in the same studies according to tumor type give strength to the findings of an increased risk for glioma and acoustic neuroma.

In summary the strengths of evidence areas follow, using the Hill criteria from 1965 (Hill 1965). For more details see also Carlberg, Hardell (2012) and Hardell et al (2011, 2012).

1. **Strength:** Ipsilateral use (tumor in the brain on same side as where wireless phone was used) finds the highest risk, especially for localisations with highest exposure (temporal lobe). Cumulative hours of use finds the highest risk
2. **Consistency**: Similar results have been found in different studies, e.g. the Hardell group and Interphone.
3. **Specificity:** Regions of brain which absorb the highest wireless phone radiation (e.g., temporal lobe) have the highest risk. Risk pattern differs according to brain tumor type.
4. **Temporality**: Those with most years since first use have the highest risk; i.e. an effect of latency time.
5. **Biological gradient:** There is a clear dose-response effect, i.e. higher cumulative use in hours of wireless phones gives a higher risk with statistically significant trend.
6. **Plausibility**: Laboratory studies show toxic effects from RF-EMF on DNA that may lead to an increased risk for brain tumors. These non-thermal effects are mediated via

the formation of reactive oxygen species (ROS).

7. **Coherence:** Several studies show by now an increasing incidence of brain tumors, especially of the type that would be expected based on epidemiological results (glioblastoma multiforme), in the most exposed parts of the brain (temporal and adjacent lobes).

8. **Experiment:** In the Hardell group studies it was shown that the group of subjects that only used the mobile phone in a car with a fixed external antenna (no exposure) did not have an increased risk for brain tumors in contrast to users without such devices (Hardell et al 2002). The EMF-RF toxic effects on DNA mediated by ROS can be prevented by antioxidants.

Sir Austin Bradford Hill (1965) noted that: "However, before deducing 'causation' and taking action we shall not invariably have to sit around awaiting the results of that research. The whole chain may have to be unravelled or a few links may suffice. It will depend on circumstances." p 295. And "If we are wrong in deducing causation from associations no great harm will be done....All scientific work is incomplete...That does not confer upon us a freedom to ignore the knowledge we already have, or to postpone the action that it appears to demand at a given time." p 300.

Using the Hill criteria on use of wireless phones and brain tumor risk infers causation of the association found in epidemiological studies. Most of these criteria are fulfilled.

Q. **Have you reviewed the joint testimony of William H. Bailey, Ph.D. and Yakov Shkolnikov, Ph.D., dated September 19, 2012, and their testimony dated November 16, 2010, which was presented jointly with Linda S. Erdreich, Ph.D.?**

A. Yes.

Q. In their testimony, Dr. Bailey and Dr. Shkolnikov cite a report by the ICNIRP Committee, which concluded, "the trend in the accumulated evidence is increasingly against the hypothesis that mobile phone use causes brain tumors." Do you agree with that conclusion?

A. No, this is not a statement based on up-to-date knowledge of the scientific literature; see above, e.g. regarding meta-analysis of the brain tumor risk. Furthermore, it should be noted that the International Agency for Research on Cancer (IARC) at WHO evaluation of the carcinogenic effect of RF-EMF on humans took place during a 24 – 31 May 2011 meeting at Lyon in France. The Working Group consisted of 30 scientists and categorised the radiofrequency electromagnetic fields from mobile phones, and from other devices that emit similar non-ionising electromagnetic fields (RF-EMF), as Group 2B, i.e. a 'possible', human carcinogen (Baan et al 2011, IARC in press).

The IARC decision on mobile phones was based mainly on two sets of case-control human studies; the Hardell group of studies from Sweden and the IARC Interphone study. Both provided complementary and supportive results on positive associations between two types of brain tumors; glioma and acoustic neuroma, and exposure to RF-EMF from wireless phones. I was an invited expert and the results from our research group were included in the evaluation as foundation for classification of the carcinogenic potential to humans from RF-EMF exposure. The Danish cohort study on mobile phone 'users' was considered to be uninformative. Besides our studies only Interphone gave results for long-term use of mobile phones (also cordless phones in our study group). The other studies were judged to be uninformative as to long-term cancer risks.

Q. Dr. Bailey and Dr. Shkolnikov testified that: "Despite the substantial increase in mobile phone use since the mid-1990s, rates of brain cancer incidence have generally remained consistent over time." Do you agree with that conclusion?

A. No, see our discussion about brain tumor incidence in our recent article in Pathophysiology (Hardell et al 2012). In fact several studies have shown increasing incidence of brain tumors.

In Denmark a statistically significant increase in incidence rate per year for brain and central nervous system tumors (combined) was seen during 2000-2009; in men +2.7 %, 95 % CI = +1.1 to 4.3 % and in women +2.9 %, 95 % CI = +0.7 to 5.2 % (NORDCAN). Furthermore, updated results for brain and central nervous system tumors have been released in Denmark. The age-standardized incidence of brain and central nervous system tumors increased with 40 % among men and 29 % among women during 2001-2010 (Sundhedsstyrelsen, 2010). A more recent news release based on the Danish Cancer Register stated that during the last 10 years there has been an increasing number of cases with the most malignant glioma type, glioblastoma multiforme (astrocytoma WHO grade IV), especially among men (http://www.cancer.dk/Nyheder/nyhedsartikler/2012kv4/Kraftig+stigning+i+hjernesvulster.htm).

Zada et al (2012) studied incidence trends of primary malignant brain tumors in the Los Angeles area during 1992-2006. The overall incidence of primary malignant brain tumors decreased over the time period with the exception of glioblastoma multiforme (astrocytoma WHO grade IV). The annual age adjusted incidence rate of that tumor type increased statistically significant in the frontal lobe of the brain with Annual Percentage Change (APC) +2.4 % to +3.0 % ($p \leq 0.001$) and temporal lobe APC +1.3 %

to +2.3 % ($p \leq 0.027$) across all registries. In the California Cancer Registry the incidence of glioblastoma multiforme increased also in cerebellum, APC +11.9 % ($p < 0.001$). That means that the incidence increased most in the parts of the brain with highest absorption of RF-EMF emissions during use of wireless phones (Cardis et al 2008) and especially for the tumor type, glioblastoma multiforme, with high risk from such emissions (Hardell et al 2012).

Of interest is also the report by de Vocht et al (2011) from England that showed for the time period 1998 to 2007 a statistically significant increasing incidence of brain tumors, the majority glioma, in the temporal lobe for men and women ($p < 0.01$), and frontal lobe for men ($p < 0.01$). That means an increasing risk for a tumor type in a specific area of the brain that would be predicted based on current knowledge on the risk pattern.

Deltour et al (2012) reported increasing glioma incidence rates in Denmark, Finland, Norway, and Sweden for the time period 1979-2008. APC increased for men with +0.4 %, 95 % CI +0.1 to 0.6 % and for women with +0.3 %, 95 % CI +0.1 to 0.5 %. A study from Australia for the time period 2000-2008 showed that APC for malignant brain tumors increased statistically significant +3.9 %, 95 % CI +2.4 to 5.4 % (Dobes et al 2011). An increase was seen among both men and women. The APC for benign tumors increased with +1.7 %, 95 % CI -1.4 to +4.9 %, thus not statistically significant.

From urban Shanghai an increasing incidence of brain and nervous system tumors for the time period 1983-2007 was reported with APC +1.2 %, 95 % CI +0.4 to 1.9 % in males and APC +2.8 %, 95 % CI +2.1 to 3.4 % in females (Ding and Wang 2011).

We reported increasing incidence of astrocytoma WHO grades I-IV during 1970-2007 in Sweden. In the age group > 19 years the annual change was +2.16 %, 95 % CI +0.25 to 4.10 % during 2000-2007, for further details see Hardell and Carlberg (2009).

In summary, it should be noted that studies on tumor type and anatomical localisation show an increasing incidence of brain tumors that would be expected based on increased risk from RF-EMF emissions.

Q. **Dr. Bailey and Dr. Shkolnikov discuss the IARC 2B classification. They emphasize a finding by the IARC that there is only "limited evidence" for cancer resulting from RF exposure. Can you explain what is meant by "limited evidence" in this context and its implications for assessing potential risks to humans from RF exposure?**

A. A summary of the evaluation has been published by Baan et al in Lancet Oncology 2011 (Baan et al 2011) and the whole Monograph is to be published (IARC in press).

The conclusion at the IARC meeting was that RF-EMF is a 'possible' human carcinogen, Group 2B of evidence. There was a very large majority among the 30 participating independent experts for that decision; almost all voted for Group 2B in the summary evaluation. I was one of the 30 invited experts. The classification system can be found in the IARC Preamble.

(http://monographs.iarc.fr/ENG/Preamble/CurrentPreamble.pdf) .

IARC evaluates the **'hazard'** of potential carcinogens, i.e. 'an agent that is capable of causing cancer under some circumstances', while a cancer **risk** is an estimate of the carcinogenic effects expected from an exposure to a cancer hazard. The IARC

monographs are an exercise in evaluating cancer hazards, despite the historical presence of the words 'risks' in the title.

IARC has categorised nearly 1 000 potentially carcinogenic **hazardous** agents, which it has studied over the past 40 years, into 5 classifications. These are differentiated by strengths of evidence.

In descending order of strengths of evidence they are:

- **Group 1**, which are '**established**' human carcinogens, such as asbestos, diesel engine exhaust, tobacco, and X-rays (109 agents);
- **Group 2A**, which are '**probable**' carcinogens, such as perchloroethylene (65 agents);
- **Group 2B,** which are '**possible**' carcinogens, such as other traffic fumes, lead, DDT and now radiofrequency electromagnetic fields including mobile phones (275 agents);
- **Group 3**, where the agent is '**not classifiable**' because the evidence is inadequate and does not permit another classification (503 agents); and
- **Group 4**, where the agent is '**probably not carcinogenic to humans**', based on fairly strong evidence **against** a cancer effect in both humans and animals (1 agent).

Source: http://monographs.iarc.fr/ENG/Classification/index.php

It should be noted that most of the agents (n=503) were evaluated as 'not classifiable' Group 3 and one as 'probably not carcinogenic to humans', Group 4. Thus classification of RF-EMF as a carcinogen (possible) is based on scientific literature. It is not an agent that cannot be classified according to its potency to be a human carcinogen. This is an important distinction regarding the carcinogenic evidence of exposure to RF-EMF, i.e. belongs to the group of agents in Group 1 or 2 with carcinogenic potential.

More discussion can be found in our chapter in Late Lessons from Early Warnings, part 2, published by European Environment Agency, Copenhagen, Denmark (Hardell et al 2013).

Q. Have there been any court cases in Europe finding that cancer was caused by EMF exposure?

A. Yes. An increased risk for leukemia among children has been reported in a small town near Rome because of the Vatican Radio broadcaster's high-powered transmitters. That is the type of malignant disease that would be expected based on scientific knowledge and the IARC evaluation of ELF-EMF as a Group 2B carcinogen to humans (IARC 2002). Italy's supreme Court has ordered Vatican Radio to compensate the victims (http://www.independent.co.uk/news/world/europe/vatican-radio-is-told-to-pay-out-over-cancer-risk-scare-2228541.html) (http://www.magdahavas.com/study-finds-vatican-radio-causes-cancer).

The first case on compensation of a patient who developed a neuroma after long-term wireless phone use has now been established in court. The Italian Supreme Court affirmed a previous ruling that the Insurance Body for Work (INAIL) must grant worker's compensation to a businessman who had used wireless phones for 12 years and developed a neuroma in the brain (www.applelettrosmog.it; www.microwavenews.com). He had used both mobile and cordless phones for five to six hours per day preferably on the same side as the tumor developed. The neuroma was located in the trigeminal Gasser's ganglion in the brain (5th cranial nerve). It is the same type of tumor as the acoustic neuroma in the 8th cranial nerve located in the same area of the brain where an increased risk of acoustic neuroma has been found among wireless phone users. The Italian case fulfils the criteria for a causal association; more than 10 years use of wireless phones, high cumulative exposure on the same side as the tumor appeared, and a tumor

type that would be predicted based on previous research on use of wireless phones and brain tumor risk. No further appeal of the Supreme Court decision is possible.

Q. Does the IARC 2B classification of carcinogenicity apply to all sources of RF-EMF?

A. Yes. In an email by Dr Baan at IARC dated 29 Aug 2011 it was stated that: "So the classification 2B, possibly carcinogenic, holds for all types of radiation within the radiofrequency part of the electromagnetic spectrum, including the radiation emitted by base-station antennas, radio/TV towers, radar, Wi-Fi, smart meters, etc.", see Exhibit C. This is an important message; the IARC decision includes "the whole radiofrequency region of the electromagnetic spectrum." The frequency range 30 kHz – 300 GHz is also defined in the publication by Baan et al (2011).

Q. Dr. Bailey and Dr. Shkolnikov testified that: "a careful scientist cannot conclude that studies and reports have identified a true, non-thermal effect." Do you agree, assuming a definition of non-thermal effect as biological effects occurring below RF-EMF intensities at which thermal effects are known to occur?

A. There are by now a vast majority of scientific studies published in peer-reviewed scientific journals showing non-thermal effects. The brain tumor risk as discussed above is one non-thermal risk.

We used serum transthyretin (TTR) as a marker of cerebrospinal fluid and blood-brain barrier damage in a cross-sectional study on 313 subjects (Söderqvist et al 2009a). We found a statistically significant positive β coefficient for TTR for time since first use of mobile phones and desktop cordless phones combined ($P = 0.03$), i.e. increased serum concentrations of TTR. The electromagnetic field parameters were similar for the phone types. In a provocation study on 41 persons exposed for 30 min to an 890-MHz GSM

signal with specific absorption rate of 1.0 Watt/kg to the temporal area of the brain, we found statistically significant increased serum TTR 60 min after exposure (Söderqvist et al 2009b).

The lipocalin type of prostaglandin D synthase or ß-trace protein (BTP) is synthesized in the choroid plexus, leptomeninges and oligodendrocytes of the central nervous system and is secreted into the cerebrospinal fluid. BTP is the key enzyme in the synthesis of prostaglandin D2, an endogenous sleep-promoting neurohormone in the brain. Exposure to RF-EMF has in some studies been associated with disturbed sleep. We studied the concentration of BTP in blood in relation to emissions from wireless phones (Hardell et al 2010, Söderqvist et al 2012b). The concentration of BTP decreased in the youngest age-group in the study, 18-30 years, with increasing number of years of use of a wireless phones. Also cumulative use in hours decreased the concentration of BTP. EMF emissions may down-regulate the synthesis of BTP in the brain. This mechanism might be involved in sleep disturbances reported in persons exposed to RF-EMF fields.

Another example of non-thermal effect is the finding that exposure to RF-EMF induces significant sperm DNA damage (Aitken et al 2005) and subsequent sperm apoptosis (De Iuliis et al 2009). Studies have shown a positive association between mobile phone use and impaired male reproduction (Agarwal et al 2009).

Specifically, the post-meiotic phase during DNA synthesis is the most vulnerable phase to environmental toxins, because during that phase the cells have lost part of their cytoplasm containing the abundant antioxidant enzymes that protect from reactive oxygen species (ROS) oxidation (Olsen et al 2005). Studies have shown that RF-EMF

may stimulate ROS generation both in vivo (Avci et al 2012) and in vitro (Lu et al 2012). Increased generation of ROS is considered to be one of the primary mechanisms that are involved in the bio-effects that are mediated by RF-EMF exposure (Friedman et al 2007).

In a recently published study, it was demonstrated that RF-EMF exposure induced the formation of oxidative base damage in a mouse spermatocyte-derived cell line (Liu et al 2013). This was mediated by ROS production. These results suggest that RF-EMF radiation emitted during mobile phone use may produce genotoxicity in the form of DNA base damage, see Graphical Abstract with Legend, Dr Liu with courtesy, Exhibit D.

To further elucidate the central role of ROS in RF-EMF exposure-induced DNA base damage, the authors used α-tocopherol pre-treatment to antagonize the oxidation of ROS; α-tocopherol is an important lipophilic antioxidant that can inactivate harmful ROS. The protective role of α-tocopherol pre-treatment confirmed that ROS are involved in RF exposure-induced DNA base damage (Liu et al 2013). The mode of action for RF-EMF-induced genotoxicity involved the induction of oxidative DNA base damage. These findings support the novel idea that low energy RF-EMF that is insufficient to directly induce DNA strand breaks may nonetheless produce genotoxic effects in the form of DNA base damage.

Another recently published study showed that 2.45 GHz low-level RF-EMF radiation induced oxidative stress and suppressed implantation or pregnancy in mice. It was also concluded that it might lead to deformity of the embryo in case pregnancy continues. The oxidative stress may lead to DNA strand breakage in the brain according to the authors and thus be a mechanism for causation of brain tumors. The effects were

non-thermal at power density = 0.033549 mW/cm^2, and specific absorption rate (SAR) = 0.023023 W/kg (Shahin et al 2013).

Antioxidants such as melatonin, vitamin C and vitamin E can alleviate the ROS oxidation and apoptosis that are induced by RF-EMF in an animal model (Oral et al 2006, Ozguner et al 2006).

The results in the study by Liu et al (2013) and Shahin et al (2013) are important findings to further elucidate the mechanisms for RF-EMF genotoxicity. These effects are clearly non-thermal. In summary these and other studies show that oxidative stress is an important mechanism for adverse health effects from RF-EMF emissions.

Non-thermal effects of electromagnetic fields on living systems have been further discussed in a monograph from the Ramazzini Institute (Giuliani, Soffritti 2010). http://www.icems.eu/papers/ramazzini_library5_part1.pdf; http://www.icems.eu/papers/ramazzini_library5_part2.pdf

Q. Is the blood-brain-barrier (BBB) a predictor of low-dose, or "non-thermal", adverse health effects?

A. Yes. In the BioInitiative Report 2012 leading researchers in this area, Dr Salford, Dr Nittby and Dr Persson conclude: "The intense use of mobile phones, not least by youngsters, is a serious memento. A neuronal damage may not have immediately demonstrable consequences, even if repeated. It may, however, in the long run, result in reduced brain reserve capacity that might be unveiled by other later neuronal disease or even the wear and tear of ageing. We cannot exclude that after some decades of (often), daily use, a whole generation of users, may suffer negative effects such as autoimmune

and neuro-degenerative diseases maybe already in their middle age". (Salford et al 2012, page 45). They continue with:

> "One remarkable observation, which we have made in our studies throughout the years, is that exposure with whole-body average power densities below 10 mW/kg gives rise to a more pronounced albumin leakage than higher power densities, all at non-thermal levels. These very low SAR-values, such as 1 mW/kg, exist at a distance of more than one meter away from the mobile phone antenna and at a distance of about 150–200 m from a base station.
>
> Further, when a mobile phone operating at 915 MHz (and its antenna) is held 1.4 cm from the human head, the very low SAR levels of 10 mW/kg exist in deep-lying parts of the human brain such as the basal ganglia, and the power density of 1 mW/kg and less is absorbed in thalamus bilaterally.
>
> With this information as a background, it is difficult to recommend safety limits as the function of existing mobile systems might not allow for limits that produce SAR levels below 1 or 0,1 mW/kg in the human brain, which are reported to cause a pathological leakage of the BBB and to neuronal damage." (Salford et al 2012, Page 45)

Thus, these very low RF-EMF levels giving neuronal damage (dark neurons) and BBB-leakage must be considered in the context of exposure from smart meters. Note the oxidative stress found in the Shahin et al (2013) study at power density 0.033549 mW/cm^2.

Q. Do you agree with their testimony that the authors of the Bioinitiative Report used flawed methods and failed to follow "the standard, scientific methods for developing exposure limits."

A. No. This is a statement that has no scientific credibility and is unfounded; see e.g. the BioInitiative Report 2012 (www.bioinitiative.org). In the Preface (http://www.bioinitiative.org/report/wp-content/uploads/pdfs/seci_2012_Preface.pdf) it is stated that:

> "Today, the BioInitiative 2012 Report updates five years of science, public health, public policy and global response to the growing health issue of chronic exposure to electromagnetic fields and radiofrequency radiation in the daily life of billions of people around the world.
>
> The BioInitiative 2012 Report has been prepared by 29 authors from ten countries, ten holding medical degrees (MDs), 21 PhDs, and three MsC, MA or MPHs. Among the authors are three former presidents of the Bioelectromagnetics Society [BEMS], and five full members of BEMS. One distinguished author is the Chair of the Russian National Committee on Non-Ionizing Radiation. Another is a Senior Advisor to the European Environmental Agency. As in 2007, each author is responsible for their own chapter.
>
> The great strength of the BioInitiative Report (www.bioinitiative.org) is that it has been done independent of

governments, existing bodies and industry professional societies that have clung to old standards. Precisely because of this, the BioInitiative Report presents a solid scientific and public health policy assessment that is evidence-based." (http://www.bioinitiative.org/report/wp-content/uploads/pdfs/seci_2012_Preface.pdf)

It should be stressed that the different chapters are written by world leading experts in the relevant scientific areas.

Q. Are there peer-reviewed studies reporting results that could support a plausible explanation for any mechanisms by which cancer could be caused by RF exposure?

A. Yes. The energy level associated with exposure is too low to cause direct DNA strand breaks and DNA crosslinks. However, DNA damages can be caused by cellular biochemical activities such as free radicals. Several studies indicate that RF-EMFs increase free radical activity in cells (Lai, Singh 1997, Phillips et al 2009). One mechanism is probably mediated via the Fenton reaction. Hydrogen peroxide is converted into hydroxyl free radicals that are potent cytotoxic molecules. This reaction is catalyzed by iron. High levels of iron are found in metabolic active cells such as cancer cells and cells undergoing abnormal proliferation, but also in brain cells. Glia cells might turn cancerous due to DNA damage, see also discussion above.

Q. Are children and adolescents more sensitive than adults to the toxic effects from RF-EMF exposure?

A. Yes. Children have smaller head and thinner skull bone than adults. Their brain tissue has also higher conductivity and these circumstances give higher absorption from RF-EMF than for adults (Cardis et al 2008, Christ et al 2010, Gandhi et al 2012). The

developing brain is more sensitive to toxins (Kheifets et al 2005) and it is still developing until about 20 years of age (Dosenbach et al 2010). The greater absorption of RF energy per unit of time, the greater sensitivity of their brains, and their longer lifetimes with the risk to develop a brain tumor and other diseases leaves children at a higher risk than adults from mobile phone radiation.

We studied the risk for glioma in different age groups. Highest risk was found for first use of mobile phone or cordless phone before the age of 20 years. Thus, mobile phone use yielded for glioma OR = 3.1, 95 % CI = 1.4-6.7 and cordless phone OR 2.6, 95 % CI = 1.2-5.5. The risk increased further for ipsilateral mobile phone use in the youngest age group to OR = 4.4, 95 % CI = 1.3-15, and to OR = 4.3, 95 % CI = 1.4-13 for cordless phone use (Hardell et al 2012).

Also for acoustic neuroma the risk was highest in the youngest age group with OR = 5.0, 95 % CI = 1.5-16 for use of mobile phone increasing to OR = 6.8, 95 % CI = 1.4-34 for ipsilateral use.

CEFALO was a multicenter case-control study on the risk for brain tumors among children and adolescents aged 7–19 years. A statistically non-significant increased risk among regular users (one call per week for at least 6 months) of mobile phones was found; OR = 1.36, 95 % CI = 0.92-2.02. This OR increased somewhat with cumulative duration of subscriptions and duration of calls (Aydin et al 2011a). No data for long-term use were given; the longest latency period was 5 years. Interestingly, further support of a true association was found in the results based on operator-recorded use for 62 cases and 101 controls, which for time since first subscription >2.8 years yielded a statistically

significant OR of 2.15, 95 % CI = 1.07-4.29, with a statistically significant trend (p=0.001).

Use of cordless phones was not well assessed. The authors stated that such use was covered only in the first 3 years of use. No explanation was given for this most peculiar definition. Wireless phone use was not considered, that is use of both mobile phones and cordless phones as the relevant exposure category, as used by the Hardell group and adopted by IARC (Baan et al 2011). Instead Aydin et al (2011a) included use of cordless phones in the 'unexposed' category when risk estimates were calculated for mobile phone use. Similarly, when use of cordless phones was analysed mobile phone use was regarded as 'no exposure'. Thus, an increased risk was potentially concealed.

Aydin et al discussed recall bias – that people tend to overestimate their number of calls – and interestingly they showed that controls overestimated their number of calls more than cases (Aydin et al 2011b). It was concluded that it was unlikely that a false positive result occurred in CEFALO and that the OR was underestimated for heavy users. Thus the results in the study were biased towards unity (no risk) for several reasons, e.g. including use of cordless phones in the 'unexposed' group and overestimated use of mobile phones among the controls. The true OR would thus have been higher than that presented in the study. The authors summarised that they "did not observe that regular use of a mobile phone increased the risk for brain tumors in children and adolescents." This statement is not correct. The results indicate an increased risk, in spite of low exposure, short latency period and limitations in study design and analyses, as we have discussed elsewhere (Söderqvist et al 2011).

Another example of the higher sensitivity of adolescents is our finding of decreased BTP concentration in blood among long-term wireless phone users in the age group 18-30 years, but not among older persons, see Hardell et al (2010) and Söderqvist et al (2012b).

Q. Should peak power densities or average power densities of RF-EMF be considered as to the health effects?

A. This is a question that has not been well studied. First it must be emphasized that a carcinogenic hazard in general exists regardless of dose for epigenetic toxic effects, i.e. no threshold. Dr Baan at IARC notes in a March 30, 2012 email that with lower dose "the hazard still exists". *See* Exhibit E.

As to ionizing radiation it is well known that the toxic effect of a specific radiation dose is higher if given as a single shot in radiotherapy than if the same dose is fractionated over several days (lower average dose over time).

By analogy peak density of RF-EMF may more accurately represent the radiation exposure to the body than power density that is a calculated average dose during a specified time, i.e. single peaks of radiation may have toxic effects and multiple peaks of radiation may have cumulative effects that are not accurately represented by averaged values. Thus, peaks of density should not be recalculated as average dose over time when the risk is estimated, instead the peak density should also be considered. The peak density is of special concern regarding e.g. the foetus (pregnant women), children, adolescents, sick and disabled.

Regarding ionizing radiation there is no homeostasis; that is that the body does not adapt to the exposure. The effects are permanent when a given part of the body is

irradiated, the given radiation dose makes additional radiotherapy impossible (depending on dose) – otherwise more serious tissue damage would occur. Regarding RF-EMF there are no well-done studies that show homeostasis in the human body for non-thermal effects. On the contrary studies show accumulating adverse health effects as exemplified by the brain tumor risk depending on cumulative does over time (dose-response). Our results of decreased BTP concentration among long-term users of wireless phones (18-30 years of age) is another example of an cumulative effect and not homeostasis. If the human body would adapt to the RF-EMF exposure no adverse health risks would occur, which is not the case.

Q. Dr. Bailey and Dr. Shkolnikov testified that: "The weight of the evidence does not support the idea that significant biological or adverse health effects can occur" from EMF-RF exposure. Do you agree with this conclusion?

A. No. On the contrary the weight of evidence shows an increased risk for certain types of brain tumors, see discussion above. The results are in accordance with what would biologically be plausible; see above the Hill (1965) criteria of evidence. On 23 January 2013 concern of adverse health effects by e.g. use of mobile phones were expressed at a meeting at the EU parliament in Brussels while Late Lessons from Early Warnings, Volume II was launched. (http://www.eea.europa.eu/acl_users/credentials_cookie_auth/login_form?came_from=http%3A//www.eea.europa.eu/publications/late-lessons-2).

Furthermore, several studies show other non-thermal effects in humans that can be linked to certain outcomes like fertility and disturbed sleep as examples, see also the BioInitiative 2012 Report (www.bioinitiative.org).

Q. In your opinion, could a careful scientist familiar with the body of knowledge on the subject reliably conclude that there are no risks of adverse health effects from the exposure to RF in the 2.4 GHz range?

A. No. The body of evidence shows risk of impaired health from the RF-EMF exposure and 2.4 GHz is included in the IARC evaluation 30 kHz – 300 kHz. Hill's analytic framework for assessing when the association is strong enough to infer causation and warrant action has been discussed above. This is particularly relevant when the question is whether a person is exposed to an agent of possible harm, such as RF-EMF, in the home or in his/her own living environments without consent.

Sir Bradford Hill in his famous article on causation provides a helpful framework for assessing the risk and he offers some very insightful comments that are useful in this context (Hill 1965). To answer those scientists who insist that every positive study be replicated, he states that "Once again looking at the obverse of the coin there will be occasions when repetition is absent or impossible and yet we should not hesitate to draw conclusions". Hill, p. 297.

To those who insist we wait until the exact causal mechanism is established, he states: "It will be helpful if the causation we suspect is biologically plausible. But this is a feature I am convinced we cannot demand. What is biologically plausible depends upon the biological knowledge of the day". P. 298.

To those who insist on more in vivo or in vitro evidence, he states: "Nevertheless, while such laboratory evidence can enormously strengthen the hypothesis and, indeed, may determine the actual causative agent, the lack of such evidence cannot nullify the

epidemiological observations in man". P. 298 "What I do not believe - and this has been suggested - is that we can usefully lay down some hard-and-fast rules of evidence that must be obeyed before we accept cause and effect." P. 299

Q. What is the message from the European Environment Agency (EEA) in Copenhagen regarding emerging technologies such as wireless networks currently in use?

A. On 23 January 2013 EEA published their 'Late Lessons from Early Warnings, Volume II' at a public meeting in the EU parliament in Brussels. Among the Key recommendations are:

- Policy makers should respond to early warnings more rapidly, the report says, particularly in cases of large scale emerging technologies. It proposes that those causing any future harm should pay for the damage.
- Risk assessment can also be improved, the report says, by embracing uncertainty more broadly and acknowledging what is not known. For example, 'No evidence of harm' has often been misinterpreted to mean 'evidence of no harm' when the relevant research was not available.
- The report calls for new forms of governance involving citizens in choices about innovation pathways and risk analysis. This would help to reduce exposure to hazards and encourage innovations with broader societal benefits. Greater interaction between business, governments and citizens could foster more robust and diverse innovations at less cost to health and the environment (http://www.eea.europa.eu/pressroom/newsreleases/the-cost-of-ignoring-the) .

One chapter deals with mobile phones and brain tumors as an emerging issue (Hardell et al 2013). The whole volume can be downloaded from the EEA website (http://www.eea.europa.eu/publications/late-lessons-2).

Q. Based on your own research and scientific knowledge what is your opinion about the risks associated with smart meters?

A. There is accumulating scientific evidence on the potential of exposure to RF-EMF to give adverse health consequences and these effects are clearly non-thermal at low intensity. Certain groups of humans such as children, adolescents, elderly and the sick and disabled are more sensitive than others. The unborn child (foetus) may be at especially high risk. Exposure to RF-EMF from smart meters is without consent in contrast to use of wireless phones that are used by the individual's own choice. I have not performed a detailed study of smart meter technology, and ultimately this is more of a policy question than a scientific one. But, in my opinion, using the Hill criteria on association or causation, there is sufficient evidence to warrant actions that would prevent or avoid exposure, and the utility should be required to prove that smart meter radiation is safe without relying on safety standards that protect only against thermal effects.

Dated this ___31st___ day of January, 2013.

Lennart Hardell

LENNART HARDELL
EXHIBIT A

Curiculum Vitae
Lennart Hardell

Education, appointments

Medical degree from University of Uppsala, Sweden, October 27, 1971.
Authorization to practice the medical profession, National Board of Health and Welfare, Stockholm, November 5, 1971.
Specialized in internal medicine, October 18, 1976.
Specialized in oncology, June 20, 1979.
Medical dissertation, University of Umeå, May 15, 1981.
Qualified as an Asssociate Professor of Oncology, University of Umeå, December 9, 1983.
Research fellow at School of Public Health, University of California, Berkeley, USA, August 20, 1984 - August 19, 1985.
Consultant at the Department of Oncology, Örebro Medical Center, Örebro, Sweden August 1, 1991.
Qualified for appointment as a Professor of Oncology in Århus, Denmark, 1992.
Research appointment at the Swedish Medical Research Council July 1, 1994 – June 30, 2000 in molecular genetic epidemiology.
Professor in Oncology, Örebro University, Örebro May 1, 2001.

Research, academic assignments

Head of a research team since the 1980's investigating mostly environmental risk factors for cancer
Supervised eight researchers for their medical dissertations.
Served in several expert panels for medical dissertations.
Chairman of Örebro County Council Radiation Protection Committee July 1, 1995 – December 31, 1998.
Vice chairman in Örebro County Council Research Committee January 27, 1992 – December 31, 1998.
Vice secretary of Örebro County Council Ethical Committe January 27, 1992 – December 31, 1998.
Deputy of Ethical Committee at Akademiska sjukhuset, Uppsala, Sweden until December 31, 1998.
Member of Research Committee at the Medical Center, Örebro.
Member of Educational Committee at Örebro Medical Center, Örebro.
Faculty member of Internationl Journal of Oncology.
Member of editorial board of American Journal of Industrial Medicine.
Continously referee for a large number of medical journals.
Partner in EU research project: Occupational risk factors for rare cancer of unknown etiology.
Member of Collegium Ramazzini 2003.

Member of Swedish expert group on 'Exposure to electromagnetic fields and the risk of malignant diseases - an evaluation of epidemiological and experimental findings'. 1995.
Member of IARC expert committee on the evaluation of the carcinogenic effect of RF-EMF on humans, 24 – 31 May 2011.
Invited to a large number of scientific meetings since the 1980's to present results from my group's scientific studies,

Published 348 research papers and 149 abstracts, short reports

Awards
Receiver of the Fernström Award, University of Umeå, October 9, 1982.
Receiver of Cancer- and Allergy Fund Environmental Research Prize, April 24, 1997, Stockholm.
Miljöpartiet de Gröna (Green Environmental Party) Research Prize, September 21, 2001.
European Journal of Cancer Prevention Research Prize November 2005
Acta Oncologica Lecture Prize 2006-03-22
Prize winner Swedish Cooperation (Änglamark) 2007

LENNART HARDELL
EXHIBIT A

Publications

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5. Hardell L, Sandström A. Case-control study: Soft-tissue sarcomas and exposure to phenoxy acids or chlorophenols. Br J Cancer 1979;39:711-7.

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LENNART HARDELL
EXHIBIT B

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LENNART HARDELL
EXHIBIT C

-----Original Message-----
From: Robert Baan <BaanR@iarc.fr>
Date: Mon, 29 Aug 2011 09:47:10
To: connieahudson@yahoo.com<connieahudson@yahoo.com>
Cc: COM (com@iarc.fr)<com@iarc.fr>
Subject: EMF Class 2B Classification

Dear Dr Hudson,

Thank you for your message, which was forwarded to me, and to which I would like to respond as follows.

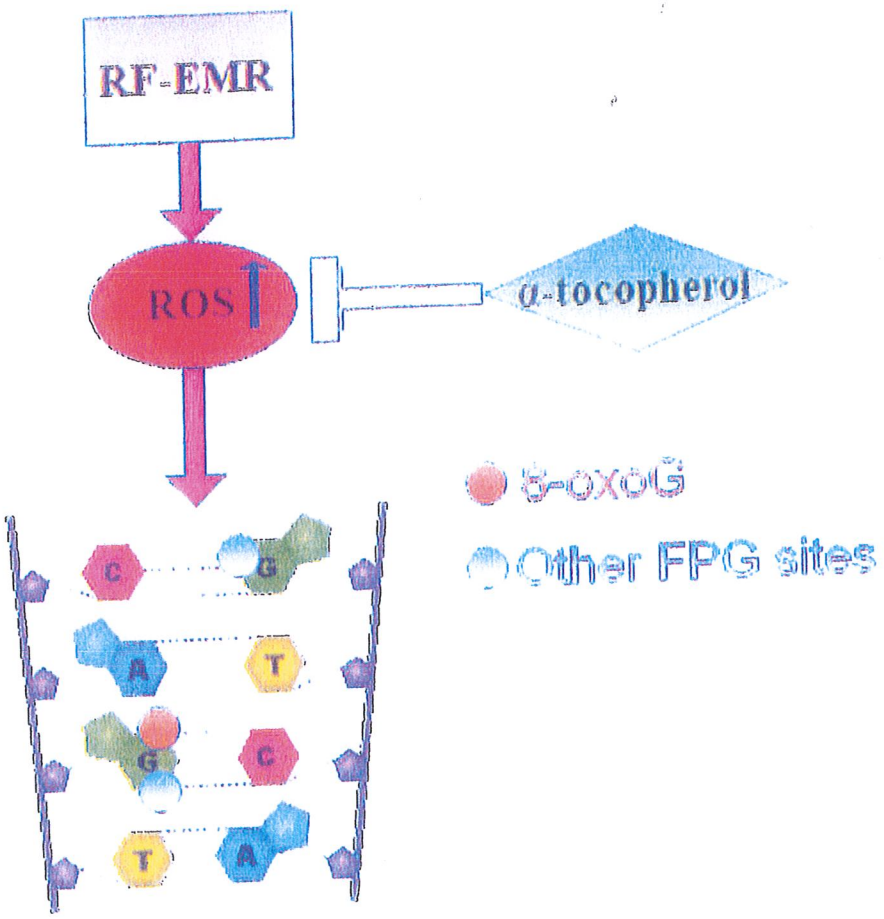
The IARC Working Group classified "Radiofrequency Electromagnetic Fields" (RF-EMF) as possibly carcinogenic to humans (Group 2B).
The information that formed the main basis for this evaluation was found in epidemiological studies on cell-phone use, where a slightly increased risk for glioma (a malignant form of brain cancer) and acoustic neuroma (a non-cancerous type) was reported among heavy users.
There were some indications of increased cancer among radar-maintenance workers (occupational exposure), but no reliable data from studies among, e.g., people living close to base-station antennas, radio/TV towers, etc (environmental exposure).
Although the key information came from mobile telephone use, the Working Group considered that the three types of exposure entail basically the same type of radiation, and decided to make an overall evaluation on RF-EMF, covering the whole radiofrequency region of the electromagnetic spectrum.
In support of this, information from studies with experimental animals showed that effects on cancer incidence and cancer latency were seen with exposures to different frequencies within the RF region.
So the classification 2B, possibly carcinogenic, holds for all types of radiation within the radiofrequency part of the electromagnetic spectrum, including the radiation emitted by base-station antennas, radio/TV towers, radar, Wi-Fi, smart meters, etc.
An important point is the radiation level. The exposure from cellular phones (personal exposure) is substantially higher and much more focused (usually on the brain) than exposures from radio/tv towers, antennas, or Wi-Fi.

I hope this is useful.

Thank you for your interest in our work.

Sincerely yours,

Robert A Baan PhD
The IARC Monographs
IARC, Lyon, FRANCE



Proposed model for the effects of RF-EMR on DNA integrity in germ cell line. Through the use of a mouse spermatocyte-derived cell line, we demonstrated that RF exposure might increase ROS production and subsequently induce the formation of oxidative base damage as evaluated by FPG-comet assay and 8-oxoG formation. The increase of ROS and the protective role of α-tocopherol pretreatment confirms that ROS are involved in RF exposure-induced DNA base damage. However, such exposure can't lead to detectable DNA strand breakage. These results may suggest that RF-EMR emitted during mobile phone use may produce genotoxicity in the form of DNA base damage other than DNA strand breaks

LENNART HARDELL
EXHIBIT E

From: Robert Baan
To: Iris Atzmon
Sent: Friday, March 30, 2012 10:21 AM
Subject: IARC's RF classification

Dear Mrs Atzmon,
The IARC Monographs classification of Radiofrequency Electromagnetic Fields (RF-EMF) covers the entire radiofrequency segment of the electromagnetic spectrum (30 kHz-300 GHz).
Within this spectrum, the electromagnetic fields around (or the radiation emitted by) mobile telephones represent the most intense and most wide-spread exposure situation, for which a small increase in risk for glioma and acoustic neuroma has been found in the group of 'heavy users'.
Because there were also some indications of increased cancer risks from studies on occupational exposures to different frequency-ranges (in the military, in the plastic-ware industry), the IARC Working Group did not want to restrict the overall evaluation to "RF-EMF from mobile phones" or to "RF-EMF from mobile phones that were used in the late 1990s" or to "RF-EMF from mobile phones that were used in the INTERPHONE study", since many other devices emit the same type of RF radiation, e.g., base-station antennas, radio/tv antennas, WiFi stations, smart meters, etc. Therefore, all these fall under the same broad evaluation of "Radiofrequency Electromagnetic Fields". This is what the Working Group discussed and decided last year. Of course, because the exposure levels for many of these other devices and exposure situations are so much lower than the exposure to someone who has a functioning cell phone against her/his ear, the risk will be considerably less (although the hazard still exists).
I hope this is sufficiently clear to be useful.
Thank you for your interest in our work.
Sincerely yours,
Robert A Baan PhD
Responsible Officer, Monograph 102 on RF-EMF
The IARC Monographs
IARC, Lyon, FRANCE